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Library
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36–INCH METER FOR WORLD'S COLUMBIAN EXPOSITION

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THE VENTURI METER

PATENTED BY

CLEMENS HERSCHEL

HYDRAULIC ENGINEER

AND BY

BUILDERS IRON FOUNDRY

MADE BY

BUILDERS IRON FOUNDRY

FOUNDERS AND MACHINISTS

PROVIDENCE, R. I., U. S. A.

1895

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VISITORS ARE WELCOME AT OUR WORKS

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6–INCH VENTURI TUBE, FLANGED ENDS

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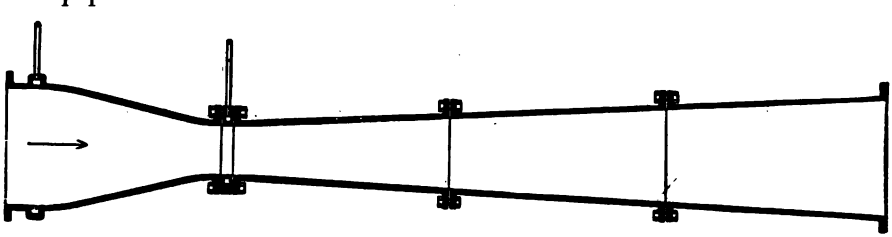
THE VENTURI METER

The Venturi Meter was designed for measuring large volumes of water, and it is now used in various Water Works on mains 6, 8, 10, 12, 13, 14, 16, 30, 36 and 48 inches diameter. For all of these sizes, experience has proved it to be satisfactory, and experiments have also shown that it measures volumes of water with accuracy on mains as large as 9 feet in diameter and on pipes as small as ¼ inch. The successful application and the correctness of the hydraulic principles upon which it is based are, accordingly, fully demonstrated.

The meter is made in two parts; the *tube*, or portion through which the water flows, and the *register*, or instrument which registers the quantity measured.

The tube has no moving parts, and consequently the meter has a number of advantages. It is not affected by water hammer, by dirt, fish, sticks or other substances in the water, and it requires no more care and is no more liable to get out of order than a piece of ordinary water pipe.



SECTION OF VENTURI TUBE

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12-INCH VENTURI TUBE, SPIGOT ENDS

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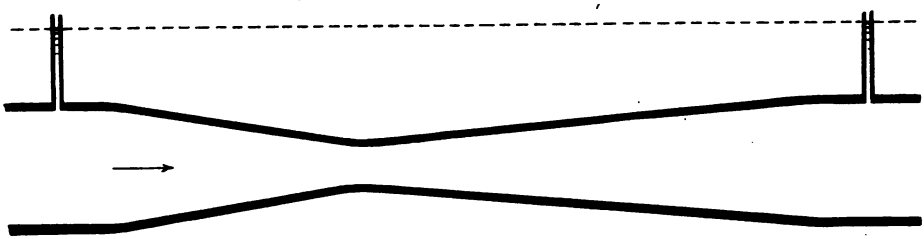
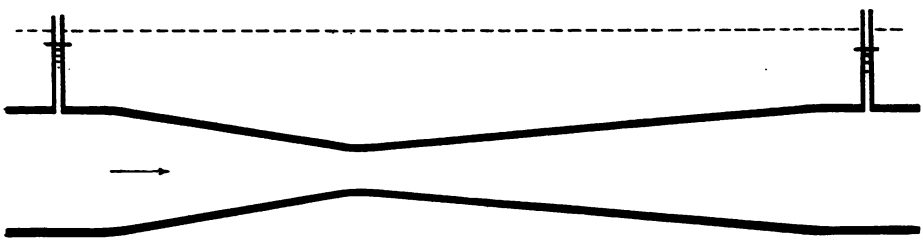
The shape of the tube is like two funnels of different tapers, connected at the small ends by a short piece of straight pipe, which is called the "throat." The opening where the water enters the tube is called the "up-stream end," and the point where it leaves the tube is called the "down-stream end" of the tube. The Tube.

At first glance it might seem that the passage of water through a contracted opening would cause a decided loss of head, or modification of the rate of flow. As a matter of fact, however, in tubes proportioned like those used in the Venturi Meter, there is, under ordinary circumstances, *practically no loss of head.* This may be seen by a simple experiment. Loss of Head.

If an open glass tube is set vertically in the up stream



end and another in the down-stream end of the meter, the level of the water in the tubes will be seen to be the same in each, when no water is flowing through the meter. When the water flows through the meter, the level of the water in both the tubes will fall, and that in the tube at



the down-stream end will be slightly lower than that at the up-stream end. This difference is the loss of head

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due to the friction in passing through the meter. The exact differences for the various velocities of flow in cubic feet per second through the throat of the meter are shown by the column "Friction head in feet" in the tables at the end of this book.

Another way of actually seeing how slight is the loss of head is by using ordinary pressure gauges in place of glass water tubes. The illustration shows two such gauges; one connected with the up-stream and the other with the down-stream end of a 36-inch meter with a flow of water 7 cubic feet per second through the throat. The variation between the two gauges is .17 of a foot, an amount too slight to be of any practical importance in Water Works systems.

The reasons why the loss of head is so slight have long been known, but are not easily explained without technical terms. They were first noted by the Italian philosopher Venturi in 1796, and for him the meter is named. Numerous investigators have studied the subject, and it is well described on pages 466 and 467 of the 9th edition of the Encyclopedia Britannica, and in Article 71 of Professor Mansfield Merriam's treatise on Hydraulics, and in the paper which received the Rowland Prize when read by the inventor of the meter, Mr. Clemens Herschel, before the American Society of Civil Engineers, December 21st, 1877. Reprints of these articles we can furnish upon application.

The construction of the meter may be modified according to different conditions under which it is used, so that, in every case, the loss of head may be reduced to any desired minimum.

In the experiment described on the preceding page it was noted that when the water was flowing through the meter tube, the level of the water in the glass tubes was

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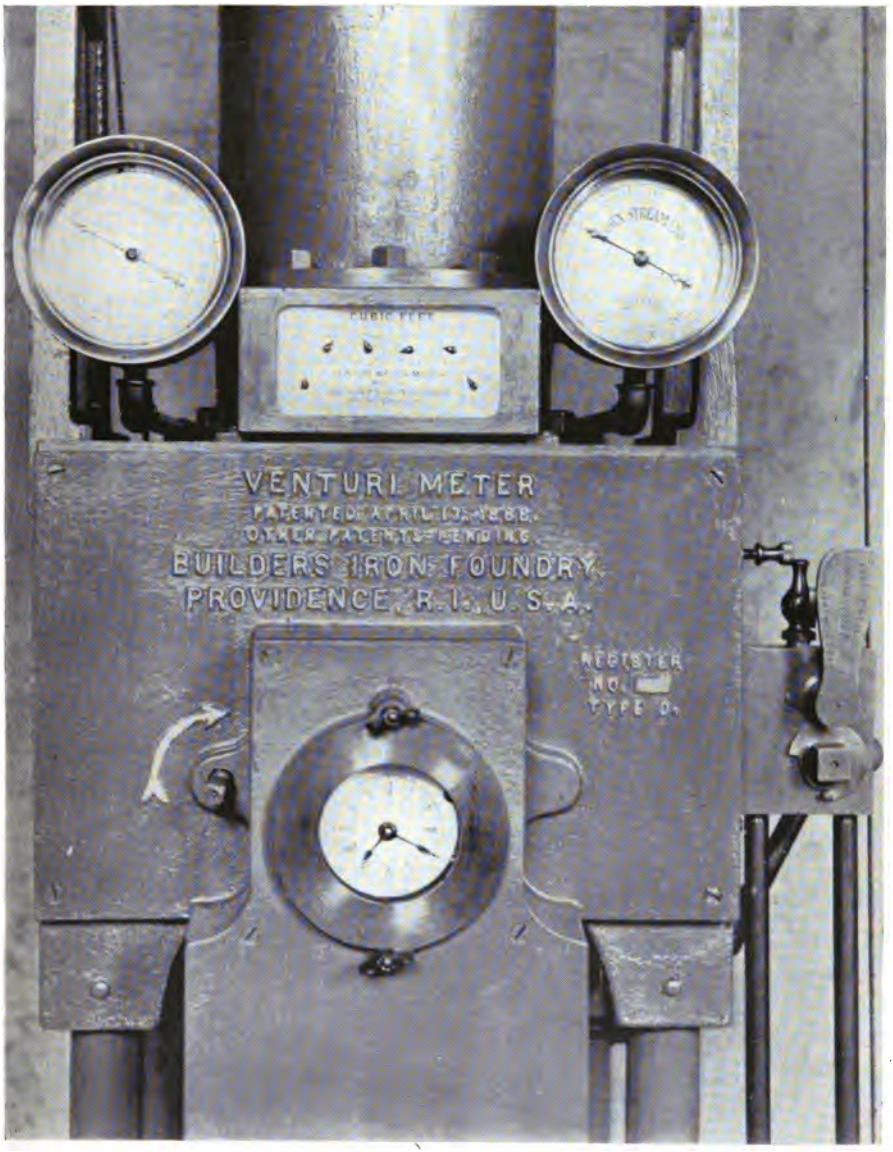

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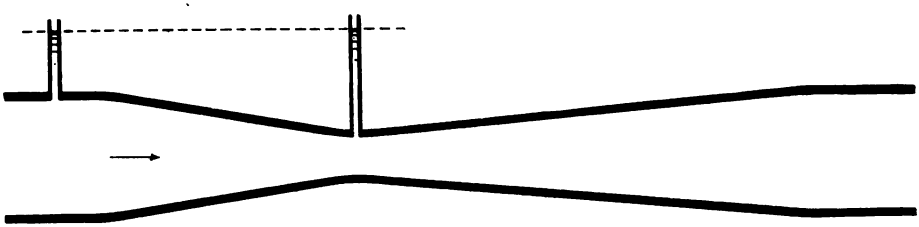
lower than when there was no flow through the meter. And if the rate of the flow is varied in this experiment, it will be seen that as the flow becomes more rapid through the meter tube, the lower will be the level of the water in the glass tubes. The water levels represent the pressures, and we can see that the faster the flow, the less the pressure.

Difference in Pressure at Up-Stream End and Throat of Meter.

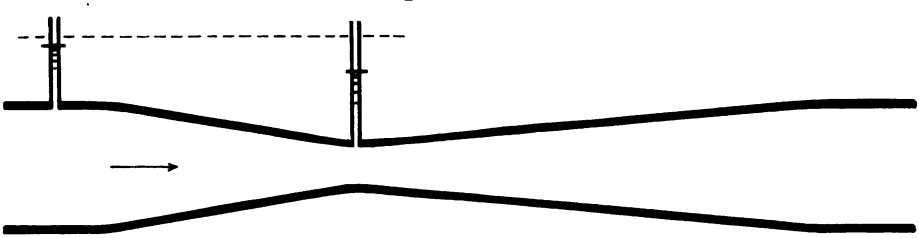
Now if we note that in flowing through the Venturi tube the water must pass through a contracted opening, it is evident that the water must flow more rapidly through the throat than through the other portions of the tube, and there will be less pressure at the throat (where the water flows most rapidly) than at the up-stream end. This may be plainly seen, and the difference in the pressure noted, in the same manner as in the preceding experiment.

If glass tubes are set in the up-stream end and in the



throat of the meter the water will be seen to be at the same level or height in both when there is no flow through the meter, that is, the pressure at both points is seen to be the same.

As soon as water begins to flow, it becomes lower in



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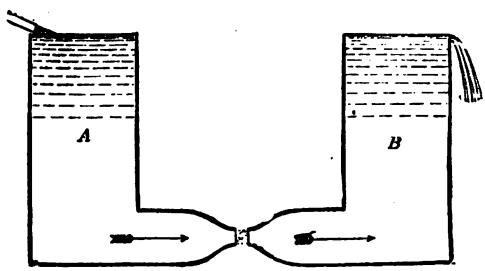
both of the tubes, and the level of the water in the tube at the throat, (where the water runs more rapidly), will be lower than in the tube at the up-stream end, *i. e.* the pressure will be less at the throat, than at the up-stream end.

Just why this is so is fully described in the scientific articles to which we have before referred; and the extent to which this may be true can perhaps best be noted in the Encyclopedia Britannica, from which we reproduce an illustration that represents water moving with such velocity that it passes from one cone to another, entirely disconnected; a condition which would show no pressure at all at the throat of a Venturi tube.



The faster the flow of water through the Venturi tube the greater the difference in the pressure at the up-stream end and at the throat of the tube: the slower the flow the less the difference in pressure.

Upon this principle the action of the meter is based, and utilizing the varying differences of pressures, the amount of flow is shown by the *register*, which forms the second part of the meter, the *tube* described being the first part.

It is necessary, in considering this subject, that we should not confuse the difference of water levels or pressures in the glass tubes at the up-stream end and at the *throat*, with the difference of pressures at the up-stream and at the *down-stream* end. The first is the difference

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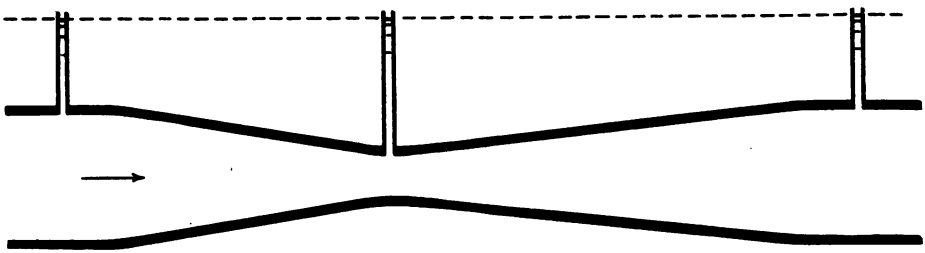
used to operate the register; the second shows the loss of head in passing the meter. The first may amount to ten or more feet, when the second might show only that number of inches; the peculiar shape of the meter insuring a recovery of head after passing the throat.

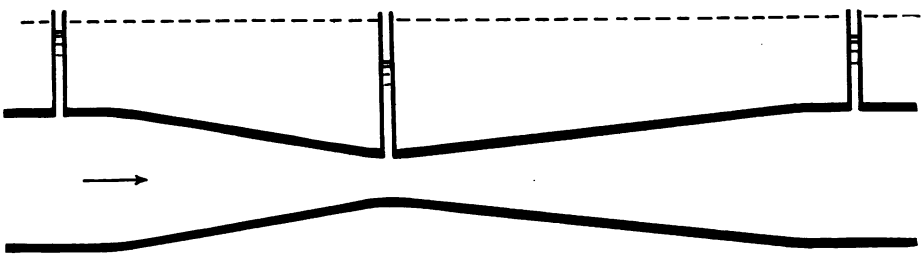
To recapitulate, and note the entire action of the tube:

Action of the Meter.

When there is no water flowing through the meter,



the pressure is the same at the up-stream end, at the throat and the down stream end. But just as soon as the water



commences to flow through the meter, the pressure falls at all three points. It falls a little more at the down stream than at the up stream end, and this difference shows the total loss of head due to the use of the meter.

As the velocity of the water is greatest at the throat, the glass tube at that point will show the greatest drop in the pressure; and, as has been said, *it is the difference of*

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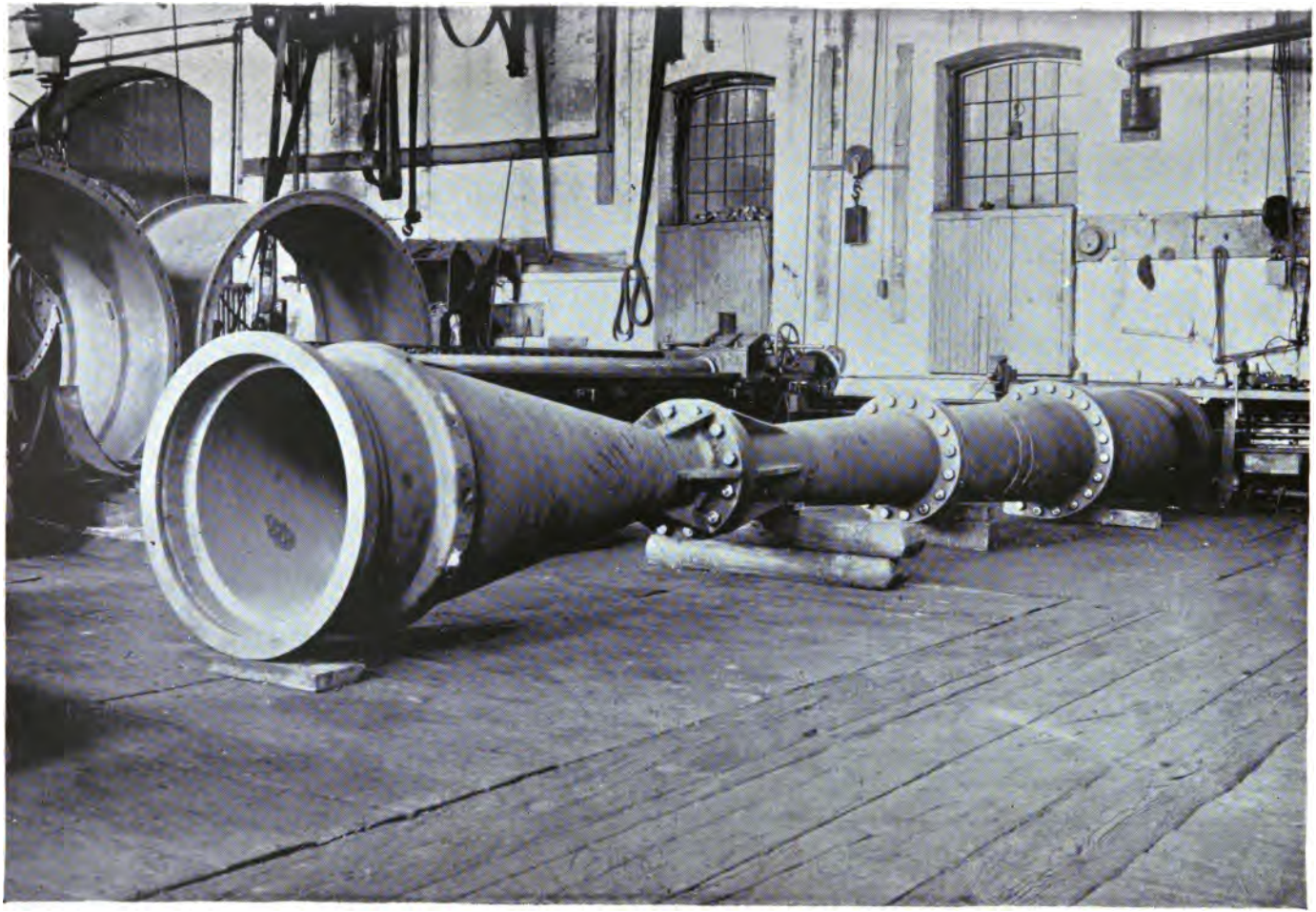

30-INCH VENTURI TUBE, BELL AND SPIGOT ENDS

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pressure at the up-stream end and at the throat which has been found to furnish an exact measure of the rate of flow through the tube, which difference, brought to act upon the register gives a record of the quantity of water passing through the meter.

Materials used in Making Tube.

The Tube is usually made of cast iron, and the throat piece is bronze, or is lined with bronze. It is placed directly in the line of the pipe, and it may be laid with no more trouble than the corresponding length of ordinary pipe which it replaces.

Connection with the Register.

The register is connected with the tube by two pressure pipes, one leading from a circular pressure chamber at the throat, and the other from a similar chamber at the up-stream end of the tube, and it may be placed at any distance, 1000 feet if desired, from the tube. There may also be an electrical device by which a record may be made at any distance, several miles if desired, from the meter.

The Register.

The Register occupies about four square feet of floor space, and the clock work which forms a part of its mechanism has to be wound once a week; beyond this it needs little attention. The record made by the register is shown by dials in the ordinary manner.

The difference of pressures or heads at the up-stream end and at the throat of the meter tube is balanced in the register by difference of levels in two columns of mercury in cylindrical receivers, one within the other, connected with the pressure pipes from the tube. The inner column carries a float, the position of which is indicative of the quantity of water flowing through the tube, the amount of the rise of the float determining the duration of contact between an integrating drum and the counters by which the flow for successive intervals is registered.

There is no friction of stuffing boxes to retard the movement of the float and impair its accuracy, for the

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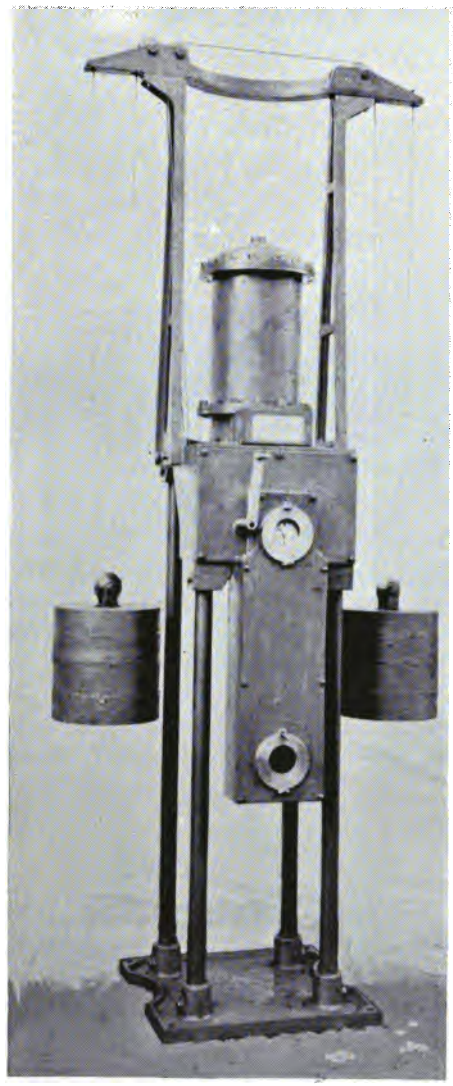

VENTURI REGISTER

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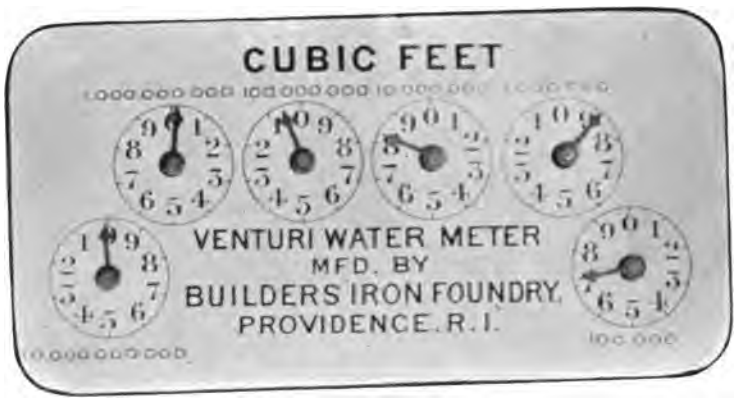

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integrating drum is enclosed in a casing or vessel which is practically an enlargement of the receiver in which the float moves, and the shafts passing through the stuffing boxes are driven positively by the motive weight; the province of the clock work being to pull a lever and set a stop at the required periods. Usually the integrating drum revolves once in every ten minutes, but this interval may be shortened if desired.

Advantages of Meter, no limit in size.

The construction of the meter offers numerous advantages. There is no limit to its size. The experiments with a tube 9 feet in diameter were entirely satisfactory, and the maximum capacity of a meter of this size exceeds 200,000,000 gallons in 24 hours, which is greater than the maximum consumption of the greatest city in the world.

Twenty foot tubes can be readily made.

Loss of Head inconsiderable.

The loss of head is inconsiderable, less than in any meter with moving parts. It is about the same as the loss caused by an ordinary gate valve.

Tube easily set and not affected by water hammer or substances in the water.

The tube may be laid with as little difficulty as a corresponding length of the pipe line with which it may be buried, and requires no special attention. It is practically a part of the pipe line and is not injuriously affected by water hammer or the most violent fluctuations of velocity or pressure. As before mentioned, it cannot be disarranged by fish, gravel or other substances carried through the pipe by the water. For this reason its accuracy is more permanent than that of an ordinary meter, which daily become less accurate as its parts are affected by wear and by substances in the water.

Accuracy.

It is accurate. The tests recorded in the following pages show a greater uniformity of action than is indicated even by the action of most carefully constructed and operated weirs.

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Prices.

The prices are reasonable, and for the large sizes are especially low, as the construction of one of the large meters does not mean a relative increase in the size of the register.

General usefulness.

The meter may be said to have created a field of usefulness for water meters which did not previously exist. In the measurement of large volumes of water, it accomplishes with little difficulty what otherwise is done only laboriously or approximately and clumsily.

Special advantages for water works.

In water works practice, this meter enables a daily record to be kept of the total quantity consumed in gravity water works; also, of the quantities consumed by large users supplied by any public water works, such as adjacent towns and cities, the several districts of one and the same city, railroads, factories and the like.

As it cannot be disarranged by substances in the water, and destroys practically none of the fire pressure, it is especially desirable when the water it carries is liable to be used for fire service.

The meter can be used as a "waste-water meter," keeping a record of the quantity passing the meter at any time. And, as an ordinary meter, its use in the detection of wastes and leaks, and as a measure of the slip of pumps, and the action of filter plants, makes it very valuable to all works for a public supply of water.

Special advantage for sewerage system.

A similar line of service is done by this meter in the case of sewerage systems, many of which, as now built, are constructed and operated for the joint benefit of several towns and cities, with the cost of operation divided pro rata between them, according to the quantity of sewage contributed.

For sewerage works a special form of tube may be used which allows of a free flow of sewage when a meter measurement is not desired at times of a small flow of

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sewage. The tube may be built of brick, and the meter is especially advantageous as it measures large and small volumes, and cannot be obstructed or disarranged by any substance metered.

Special advantages for irrigation works.

For irrigation works this meter accomplishes what has hitherto been desired, but has not been practicable. It enables water for irrigation purposes to be sold strictly by measure, and with practically no constraint as to the time when it may be drawn.

Where there is no head, as in open channels, or only a small head on the main pipe, the tube may be made of wood, and where a comparatively small range of capacity will suffice, the recorder is built without a mercury gauge, being operated directly by the water column. This makes a much less costly meter.

The tube may be set in line of a conduit or pipe, or in line of an open ditch or channel.

Special advantages for mills and factories.

In the case of water powers, this meter is valuable in determining the quantity of water drawn by tenants of water rights for power, or for wash water and other purposes other than power.

It offers to mills and factories a means of checking charges for power, or for ascertaining the amount of power used. It can be submerged in a flume or penstock, and enables large bodies of water to be measured regularly and accurately. Where it is not desired to use it continuously, a by-pass is used to carry the water by the meter.

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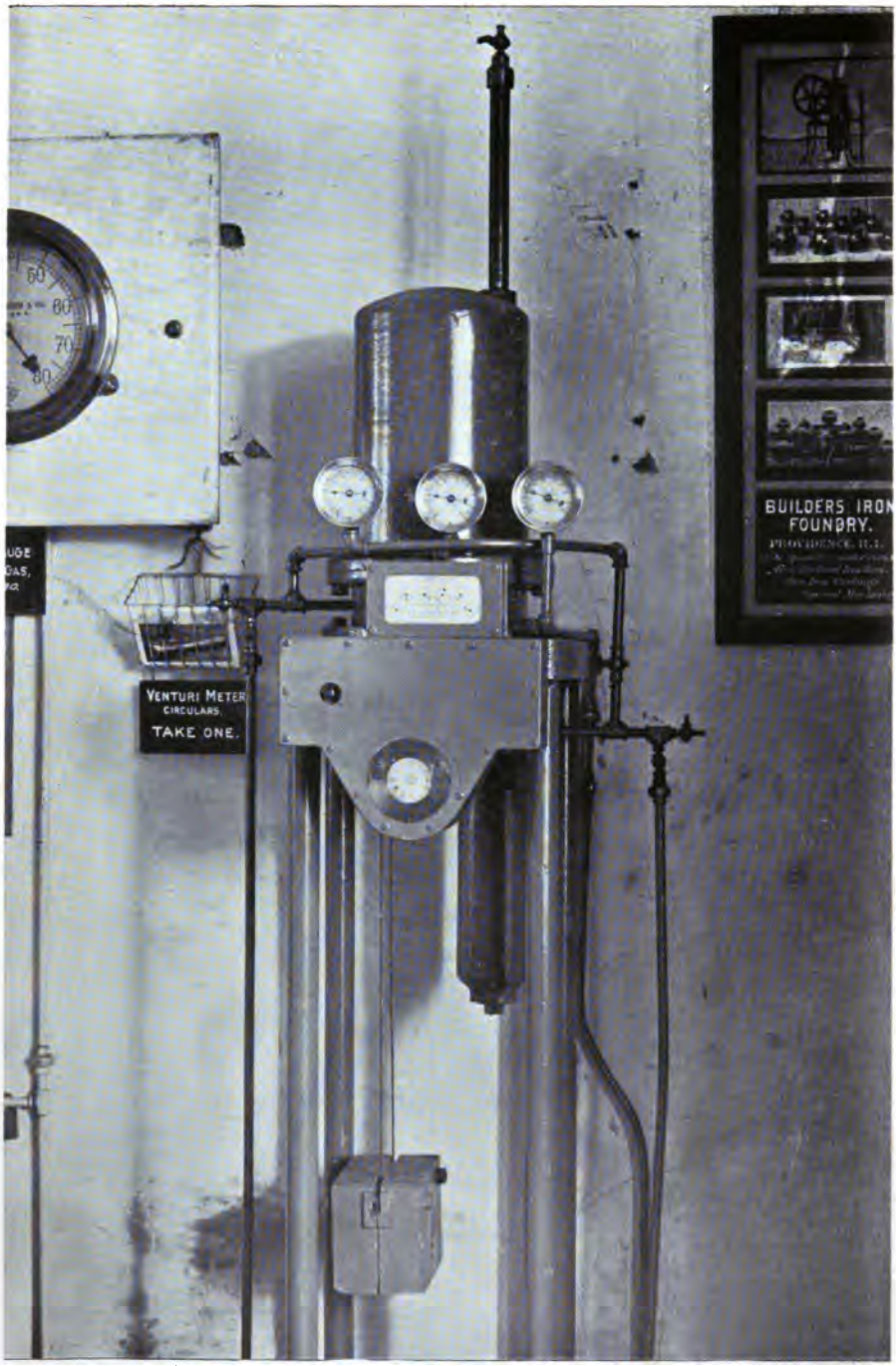

REGISTER IN PAVILION OF THE WAUKESHA HYGEIA MINERAL SPRINGS COMPANY
WORLD'S COLUMBIAN EXPOSITION, CHICAGO, ILL.

This type of Register has been superseded by that shown on page 15.

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Loss of Head

The illustration on the opposite page is taken from a photograph of the recorder of the 6-inch meter, at the pavilion of the Waukesha Hygeia Mineral Springs Company, World's Columbian Exposition, Chicago, and is published to show how little loss of head is caused by operation of the Venturi Meter under normal conditions.

The gauge at the left indicates 28.1 lbs. the pressure at inlet of the meter tube; the center gauge, about 27 lbs., the pressure at the throat; and the gauge at the right, 28 lbs., the pressure at the outlet of meter. When the photograph was taken the flow through meter was about 3 gallons per second.

The readings do not appear as close as they actually are because the zero points of the three gauges are not in the same relative positions.

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3–INCH VENTURI METER

LABORATORY MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Tests

The tests have been very thorough, the tube and the register, separately and together, having been the subjects of elaborate experiments. Accounts of some of the tests are given in the following pages, but the most extended experiment with the tubes is described in Mr. Herschel's Rowland Prize Paper. The water used in that test was measured in a water tight chamber, the contents of which could be known at any time with almost absolute accuracy, and the results of the test are beyond question. They demonstrated the permanent and entire accuracy of the meter.

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Register in Netherwood Pumping Station of the Plainfield Water Supply Company

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Test of 12-inch Meter

At Netherwood, N. J.

This test was made under the direction of Mr. Frank Bergen, President of the Plainfield Water Supply Co., and lasted six hours. The flow through the meter varied from 44 to 225 cubic feet per minute, and the total quantity registered exactly 28,000 cubic feet, the test being completed when the record showed that this quantity had passed through the meter.

The water was taken from the stand-pipe of the Plainfield Water Supply Company, and during the test the water in the stand-pipe dropped from 95.1 feet to 37.9 feet, making the total fall 57.2 feet. The area of the stand-pipe was taken equal to 415 square feet, multiplying this by 57.2, the number of feet showing the difference in the height of the water before and after the test, the result is 28,085.2 cubic feet, being the total quantity taken from the tank by actual measurement. The difference between this amount and the 28,000 cubic feet registered by the meter, is 85.2 cubic feet, making a difference, between the stand-pipe and the meter measurement, of 3-10 of 1 per cent.; that is, the meter registration was 3-10 of 1 per cent. less than the quantity of water as measured in the riveted stand-pipe.

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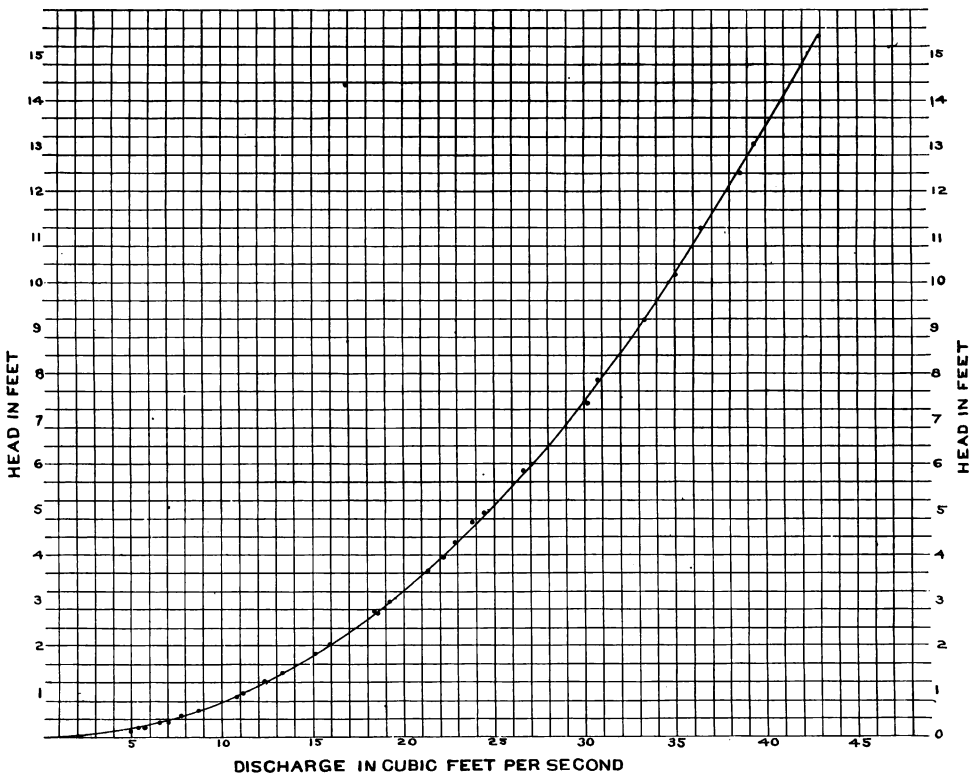

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Test of Register for 36-inch Meter

The diagram on the opposite page illustrates a test of the register of the 36″ meter which measured the main water supply of the World's Columbian Exposition. The difference between the pressures or heads at the up-stream end and at the throat of the tube is called "head in feet" in the diagram, and the curve shows the number of cubic feet of water that *theoretically* would flow through the tube per second for these various "heads." The *actual* flow shown by the register is indicated by the position of the dots on or near the curve.

To obtain the theoretical flow for 6 feet of head, for example, follow the horizontal line from the point marked 6 in the illustration until the curve is reached, then follow down a vertical line from that point to the scale at the lower edge of the diagram and 27.2 cubic feet per second will be seen to be the theoretical flow. The actual flow, as indicated by the register, is shown by the position of the dot on the horizontal line for this head. Following down a vertical line from this dot to the lower edge of the diagram it is seen that 27.1 cubic feet per second is the actual flow shown by the register, or a variation from the theoretical flow of less than ½ of 1 per cent.

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REGISTER VAULT OF THE EAST JERSEY WATER COMPANY, NEAR MACOPIN, N. J.

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Test of Register of 48-in. Venturi Meter

AT THE

Macopin Intake of the East Jersey Water Co., near Charlottsburg, N. J.

The Tube or meter proper, was rated before the Register was connected, that is, water was allowed to flow through the tube, the discharge was measured by means of a carefully constructed weir, and the "Head on Venturi," (or difference in pressure at the throat and up-stream end of the tube) was determined by observations of the difference in water height in two glass piezometer tubes. Repetitions of this experiment with different known quantities of water flowing through the tube determined the "Head on Venturi" for the entire range of the meter. In other words, the co-efficients of flow were established for this particular meter, set in place. The Register was then connected to the same pipes that conveyed pressure to the piezometer tubes, and during the test the quantity of water passing through the meter was calculated by means of the relations previously established, between the "Head on Venturi" and the flow. The difference between the quantities registered and calculated were tabulated in gallons and in per-centages of the quantity measured. The average error of the Recorder was thus seen to be about fifteen hundredths of one per cent. during the two weeks' test.

The record during the test and monthly record of the meter is shown by the following tables:

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Date, 1893.	Head on Venturi.	Galls. of water passed by Meter as calculated by observed water height in glass tubes.	Galls. of water passed by Meter as shown by dial of Recorder.	Difference between gallons calculated and indicated by Recorder.	Error of Recorder in per cent. of quantity measured.
Aug. 24	2.09 avg. for 24 hrs.	20,520,000.	20,380,000.	140,000.	—0.682
" 25	2.08 " " 24 "	20,480,000.	20,420,000.	60,000.	—0.293
" 26	2.05 " " 24 "	20,340,000.	20,370,000.	30,000.	+0.147
" 27	2.045 " " 24 "	20,310,000.	20,350,000.	40,000.	+0.197
" 28	2.044 " " 24 "	20,300,000.	20,290,000.	10,000.	—0.05
" 29	2.06 " " 24 "	20,380,000.	20,360,000.	20,000.	—0.098
" 30	2.06 " " 24 "	20,380,000.	20,450,000.	70,000.	+0.343
" 31	2.05 " " 24 "	20,340,000.	20,450,000.	110,000.	+0.539
Sept. 1 a*	2.07 " " 6.5 "				
	2.50 " " 17.5 "	21,870,000.	21,810,000.	60,000.	—0.274
" 2 b*	2.51 " " 14.5 "				
	2.06 " " 9.5 "	21,630,000.	21,730,000.	100,000.	+0.462
" 3 c*	2.07 " " 13 "				
	1.33 " " 11 "	18,560,000.	18,550,000.	10,000.	—0.052
" 4	2.065 " " 24 "	20,400,000.	20,450,000.	50,000.	+0.245
" 5	2.08 " " 24 "	20,480,000.	20,400,000.	80,000.	—0.391
" 6	2.07 " " 24 "	20,440,000.	20,450,000.	10,000.	+0.049
" 7	2.08 " " 24 "	20,480,000.	20,450,000.	30,000.	—0.15
" 8	2.09 " " 24 "	20,520,000.	20,530,000.	10,000.	+0.05
" 9	2.097 " " 24 "	20,580,000.	20,630,000.	50,000.	+0.25
" 10 d*	2.08 " " 18.3 "				
	1.31 " " 5.7 "	19,480,000.	19,670,000.	190,000.	+0.98
" 11 e*	1.31 " " 6.5 "				
	2.07 " " 17.5 "	19,310,000.	19,500,000.	190,000.	+0.98
" 12	2.05 " " 24 "	20,340,000.	20,470,000.	130,000.	+0.64
" 13	2.077 " " 24 "	20,460,000.	20,420,000.	40,000.	—0.20
" 14	2.077 " " 24 "	20,460,000.	20,460,000.	00,000.	0.0
" 15	2.073 " " 24 "	20,450,000.	20,450,000.	00,000.	0.0
" 16	2.073 " " 24 "	20,450,000.	20,470,000.	20,000.	+0.1
" 17 f*	2.07 " " 10.8 "				
	1.33 " " 13.2 "	18,200,000.	18,430,000.	230,000.	+1.26
" 18	2.063 " " 24 "	20,420,000.	20,450,000.	30,000.	+0.15
" 19	2.07 " " 24 "	20,440,000.	20,450,000.	10,000.	+0.05
" 20	2.06 " " 24 "	20,390,000.	20,450,000.	60,000.	+0.29
		568,410,000.	569,290,000.	880,000.	+0.15

* a. Gate changed at 6.30 A. M.
b. Gate changed at 2.30 P. M.
c. Gate changed at 6.30 A. M. and 5.30 P. M.
d. Gate changed at 6.20 P. M.
e. Gate changed at 6.30 A. M.
f. Gate changed at 6.50 A. M. and 8 P. M.

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MONTHLY RECORD OF 48-INCH VENTURI REGISTER AT MACOPIN INTAKE

MONTHS	No. of days covered by test	Variation in per cent.			No. of days in which the variation was		REMARKS
		Greatest in any one day	Least in any one day	Average for the month	Plus	Minus	
1893							2 days no vari'tion
September	30	+1.26	0.00	+0.26	20	8	
October	19	+1.16	—0.10	—0.03	8	11	1 " " "
November	10	—1.63	—0.34	—0.41	3	6	
1894							
March	24	—1.60	+0.05	—0.45	6	18	1 " " "
April	29	+2.25	0.00	—0.73	4	24	2 " " "
May	31	—1.55	0.00	—0.09	12	17	1 " " "
June	30	—2.33	0.00	—0.39	8	21	

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36-INCH METER AT NEW ORLEANS

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TABLE

SHOWING QUANTITY OF WATER PASSING THROUGH VENTURI METER TUBES OF DIFFERENT SIZES (THROAT AREA $\frac{1}{9}$ OF MAIN), WITH CORRESPONDING VELOCITY OF FLOW IN THROAT, "HEAD ON VENTURI," AND "FRICTION HEAD."

"Head on Venturi" is the difference of pressure, in feet of water, at throat and up-stream end of tube.

"Friction Head" is the difference of pressure, in feet of water, at up-stream and down-stream ends of tube, or the loss of head due to introduction of meter tube.

Vel. through throat in ft. per second.	Quantity in Cubic Feet per Second.			Head on Venturi, in feet.	Friction Head in feet.
	12-inch Meter.	15-inch Meter.	18-inch Meter.		
2.	.174	.272	.392	.061	.006
2.5	.217	.340	.490	.097	.015
3.	.260	.408	.588	.14	.025
3.5	.303	.476	.686	.19	.04
4.	.346	.544	.784	.25	.05
5.	.433	.680	.980	.39	.07
6.	.520	.816	1.176	.56	.10
7.	.607	.952	1.372	.76	.12
8.	.694	1.088	1.568	1.00	.15
9.	.781	1.224	1.764	1.2	.21
10.	.868	1.360	1.960	1.5	.26
12.	1.042	1.632	2.352	2.26	.36
14.	1.216	1.904	2.744	3.10	.47
16.	1.390	2.176	3.136	4.05	.63
18.	1.564	2.448	3.528	5.16	.79
20.	1.738	2.720	3.920	6.40	1.00
24.	2.086	3.264	4.704	9.21	1.36
28.	2.434	3.808	5.488	12.73	1.90
32.	2.782	4.352	6.272	17.25	2.65
36.	3.130	4.896	7.056	21.75	3.05
40.	3.478	5.440	7.840	27.	3.80
50.	4.346	6.800	9.800	42.	7.70

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36-INCH METER AT NEW ORLEANS

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TABLE

SHOWING QUANTITY OF WATER PASSING THROUGH VENTURI METER TUBES OF DIFFERENT SIZES (THROAT AREA $\frac{1}{9}$ OF MAIN), WITH CORRESPONDING VELOCITY OF FLOW IN THROAT, "HEAD ON VENTURI," AND "FRICTION HEAD."

"Head on Venturi" is the difference of pressure, in feet of water, at throat and up-stream end of tube.

"Friction Head" is the difference of pressure, in feet of water, at up-stream and down-stream ends of tube, or the loss of head due to introduction of meter tube.

Velocity through throat in feet per second.	Quantity in Cubic Feet per Second.					Head on Venturi, in feet.	Friction Head, in feet.
	48-inch Meter.	54-inch Meter.	60-inch Meter.	72-inch Meter.	80-inch Meter.		
2.	2.792	3.534	4.363	6.183	8.552	.061	.006
2.5	3.490	4.417	5.453	7.728	10.690	.097	.012
3.	4.188	5.300	6.543	9.273	12.828	.14	.016
3.5	4.886	6.183	7.633	10.818	14.966	.19	.023
4.	5.584	7.066	8.723	12.363	17.104	.25	.028
5.	6.980	8.833	10.904	15.454	21.380	.39	.04
6.	8.376	10.600	13.085	18.545	25.656	.56	.06
7.	9.772	12.367	15.266	21.636	29.932	.76	.085
8.	11.168	14.134	17.447	24.727	34.208	1.00	.11
9.	12.564	15.901	19.628	27.818	38.484	1.2	.14
10.	13.960	17.668	21.809	30.909	42.760	1.5	.17
12.	16.752	21.202	26.172	37.092	51.312	2.26	.25
14.	19.544	24.736	30.535	43.275	59.864	3.10	.33
16.	22.336	28.270	34.898	49.458	68.416	4.05	.43
18.	25.128	31.804	39.261	55.641	76.968	5.16	.55
20.	27.920	35.338	43.624	61.824	85.520	6.4	.68
24.	33.504	42.406	52.350	74.190	102.624	9.21	.99
28.	39.088	49.474	61.076	86.556	119.728	12.73	1.34
32.	44.672	56.542	69.802	98.922	136.832	17.25	1.75
36.	50.256	63.610	78.528	111.288	153.936	21.75	2.25
40.	55.840	70.678	87.254	123.654	171.040	27.	*2.90*
50.	69.800	88.346	109.063	154.563	213.800	42.	*6.00*

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HOUSE FOR REGISTER 36-IN. VENTURI METER, WORCESTER WATER WORKS, WORCESTER, MASS.

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TABLE

SHOWING QUANTITY OF WATER PASSING THROUGH VENTURI METER TUBES OF DIFFERENT SIZES (THROAT AREA $\frac{1}{9}$ OF MAIN), WITH CORRESPONDING VELOCITY OF FLOW IN THROAT, "HEAD ON VENTURI," AND "FRICTION HEAD."

"Head on Venturi" is the difference of pressure, in feet of water, at throat and up-stream end of tube.

"Friction Head" is the difference of pressure, in feet of water, at up-stream and down-stream ends of tube, or the loss of head due to introduction of meter tube.

Vel. through throat in ft. per second.	Quantity in Cubic Feet per Second.						Head on Venturi, in feet.	Friction Head, in feet.
	21-inch Meter.	24-inch Meter.	27-inch Meter.	30-inch Meter.	36-inch Meter.	42-inch Meter.		
2.	.534	.698	.883	1.090	1.570	2.138	.061	.006
2.5	.667	.872	1.103	1.362	1.962	2.672	.097	.015
3.	.800	1.046	1.323	1.634	2.354	3.206	.14	.02
3.5	.933	1.220	1.543	1.906	2.746	3.740	.19	.025
4.	1.066	1.394	1.763	2.178	3.138	4.274	.25	.03
5.	1.333	1.743	2.204	2.723	3.923	5.343	.39	.05
6.	1.600	2.092	2.645	3.268	4.708	6.412	.56	.07
7.	1.867	2.441	3.086	3.813	5.493	7.481	.76	.10
8.	2.134	2.790	3.527	4.358	6.278	8.550	1.00	.13
9.	2.401	3.139	3.968	4.903	7.063	9.619	1.20	.17
10.	2.668	3.488	4.409	5.448	7.848	10.688	1.50	.22
12.	3.202	4.186	5.292	6.538	9.418	12.826	2.26	.32
14.	3.736	4.884	6.175	7.628	10.988	14.964	3.10	.42
16.	4.270	5.582	7.058	8.718	12.558	17.102	4.05	.53
18.	4.804	6.280	7.941	9.808	14.128	19.240	5.16	.67
20.	5.338	6.978	8.824	10.898	16.698	21.378	6.40	.82
24.	6.406	8.374	10.590	13.078	18.838	25.654	9.21	1.20
28.	7.474	9.770	12.356	15.258	21.978	29.930	12.73	1.68
32.	8.542	11.166	14.122	17.438	25.118	34.206	17.25	2.10
36.	9.610	12.562	15.888	19.618	28.258	38.482	21.75	2.7
40.	10.678	13.958	17.654	21.798	31.398	42.758	27.00	3.3
50.	13.346	17.446	22.063	27.246	39.246	53.446	42.00	7.

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HOUSE FOR REGISTER, 16-INCH VENTURI METER, WATER WORKS, ST. PAUL, MINN.

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Appendix

Abstract from Records of American Society of Civil Engineers Mr. Herschell in Reply to Questions Asked at the time of Reading the Rowland Prize Paper.

In its completed form, the Venturi Meter is an instrument to gauge the quantity of water flowing in a pipe, by measurement of an abrupt, artificially produced depression in the hydraulic gradient. To explain more particularly, suppose a pipe full of water, the water in a state of rest. Piezometers placed on such a pipe, will have the water stand in them at points situated all on one level.

In Plate XL, suppose *PP* to be such a pipe, at one time "submerged," or under a head, to the extent 1 *P*, and again, only to the extent *a P*. Next, suppose the water to take any velocity through the pipe (no meter being yet supposed inserted), sufficient to cause the water in the piezometer to stand on the line 22 and *bb*, respectively, according as the amount of submergence was originally 1 *P* or *a P*. This line 22, or *bb*, is what I have called the "hydraulic gradient." Next, suppose the meter inserted in the pipe; upon which, the water level at the up-stream piezometer will remain at 2, but at the piezometer which is set on the venturi, the water level or

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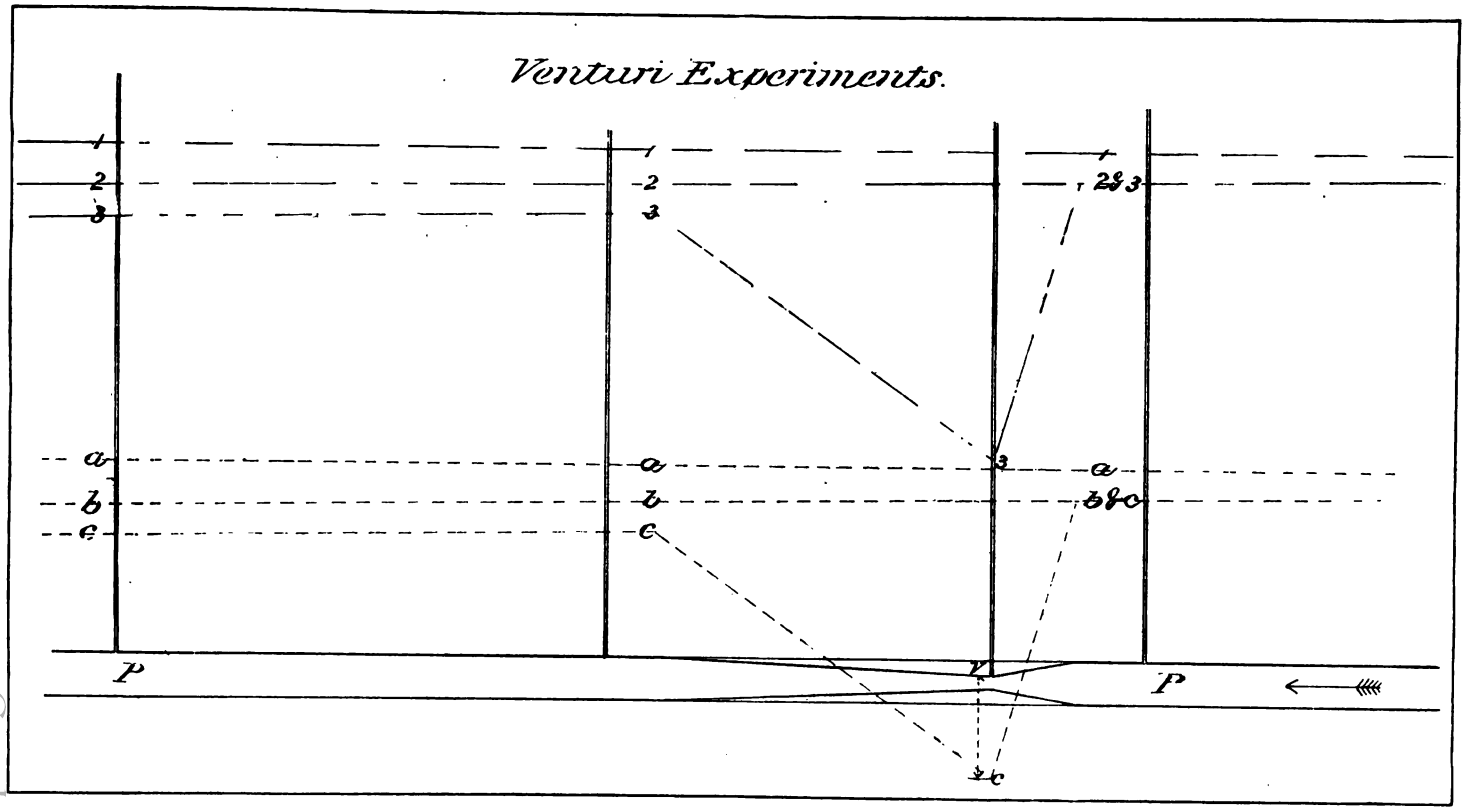
PLATE XL.



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hydraulic gradient will drop to 3, then rise again, at the end of the meter, up to within a small distance below its former position (this distance representing the "loss of head" due the whole apparatus), then will run parallel to its former position, as shown at 3 on the down stream piezometers. The experiments have shown that the velocity of the water, or the discharge through the narrowest section of the meter through the "venturi," is that due the head on the venturi (as represented by the difference in level of two points in the "hydraulic gradient," one taken just above the meter and the other at the venturi), with a co-efficient, which is remarkably constant, whether applied to a rough meter and for a 9-foot pipe, or to smooth one for a 1-foot pipe, and for all velocities through the pipe ranging from ½ to six feet per second. If this co-efficient is taken without further measurement at 98 per cent., we may be certain from experiments so far made that we shall rarely be over 2 per cent. out of the way. Going back a little, let us take now the other case of submergence, originally represented by the hydraulic gradients *aa* and *bb*. It is plain that the water level in the piezometer which is set on the venturi cannot fall below the surface of the stream spouting through the venturi.

But so much of the "depression" in the hydraulic gradient at this point due the velocity of the water, which lies below the surface of the stream just named, will be indicated or exhibited by the sucking action or aspiration or "vacuum" spoken of in the paper; and in measures of a column of water lifted, will exactly equal that portion of the "depression," as shown in Plate XL (or as it may be computed), which lies below the surface of the stream spouting through the venturi. In Plate XL it is equal to the distance *v c*, indicated by the reference marks.

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This is the case in which some form of vacuum-gauge is necessary at the venturi, when separate gauges are used at the up-stream piezometer and at the venturi, as was done during the experiments related in the paper. No such complication is necessary however, in practice. As the measure sought is the difference of pressure immediately above the meter and at the venturi, a single pressure-gauge suffices. The logical possibilities, depending on the degree of submergence of, and velocity through the pipe, are three, and are exhibited by the table:

	Above the Meter	At the Venturi
1	Pressure	Pressure
2	Pressure	Vacuum
3	Vacuum	Vacuum

But in any event there will be a "head on the venturi," or, what is the same thing, Column 1 minus Column 2 of the tabular quantities will always be positive and will indicate pressure, and may be measured by a single-pressure gauge.

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